strength of the cone and still provide for drilling over the full bottom of the hole.

The bottom of each of the arms **61** has a profile approximately the same as the profile of the cutter cones **62.** Each arm has three diamond cutters **68** mounted for cutting at the gage of the hole being drilled. These diamond cutters are illustrated schematically in FIG. **7** in the same manner as FIGS. **5** and **6** but it will be appreciated that they are of the type hereinabove described and illustrated in FIG. **4.** The gage diamond cutters **68** drill in the same annular path as the gage carbide inserts **64** on the two rolling cone cutters.

Each arm also has a plurality of additional diamond cutters **69** spaced inwardly from the gage row **68.** These additional diamond cutters are positioned in annular paths corresponding to the additional annular paths drilled by the carbide inserts **66** and **67** in the rolling cone cutters. Thus, the annular paths on the bottom of a hole are drilled by both carbide inserts and diamond cutters.

As mentioned above, carbide inserts on rolling cone cutters conventionally drill by either of two actions. When the axis of the cone intersects the axis of the rock drill the principal drilling action is due to crushing of the rock by the carbide inserts due to the heavy weight applied to the drill bit. When the axis of a cutter cone is offset slightly from the axis of the drill bit there is some sliding or skidding action by the cone and an appreciable amount of gouging action during drilling. The gouging action of an offset bit is desirable in relatively softer rock. The primary crushing action of a non-offset drill bit is ordinarily preferred in relatively harder rock.

Either an offset or non-offset roller for primarily gouging or crushing action, respectively, can be used in the arrangement of FIG. **7.** In either case the path that is drilled by each row of carbide inserts is rough since the loads are applied intermittently on the rock.

The diamond cutters cut by a shearing action as they are dragged across the rock. Thus a groove cut by a diamond cutter is ordinarily rather smooth except as chips from the rock may leave a slightly roughened surface.

The diamond cutters in the embodiment of FIG. **7** are arranged in the same annular paths as the carbide inserts on the rolling cone cutters. Thus, the rough groove formed by the carbide inserts is scraped smooth by the diamond cutters. This reduces the load on the diamond cutters for a given volume of rock removed from the bottom of the hole. Further, it minimizes or eliminates the possibility of "tracking" by the rolling cone cutters where the carbide inserts repeatedly contact the same point on the bottom of the hole and drill inefficiently. Thus, a combination of diamond cutters and rolling cone cutters on a rock drill where both drill in the same profile on the bottom of a hole can be more effective in some formations than either diamond cutters or rolling cone cutters alone.

In the embodiment of FIG. **7** substantially the entire bottom of the hole is drilled by both carbide inserts and diamond cutters. If desired, either can be arranged so that different portions are drilled, with only a portion of the bottom of the hole being drilled by both carbide inserts and diamond cutters.

The carbide inserts on the rolling cone cutters in the embodiment of FIG. **7** protrude from the surface thereof a distance less than the full length of the diamond cutters. Thus, as described above the depth of penetration of the diamond cutters is limited to minimize wear on the carbide slug mounting the diamond plate and minimizing the impact loading on the diamond. Criteria as set forth above are employed whether the carbide inserts and diamond cutters drill in similar or different portions of the bottom of a hole.

Although limited embodiments of drill bits having diamond cutters with means for limiting penetration of the diamond cutters have been described and illustrated herein, many modifications and variations will be apparent to one skilled in the art. Thus, for example, although the drag cutters are described herein in terms of the carbide slugs bearing a diamond plate currently available commercially, other variations of drag cutter are also suitable. The drag cutter may have other configurations instead of the essentially cylindrical end provided by the diamond plates.

In some embodiments tungsten carbide or other hard drag cutters may be used with depth of penetration limited by rollers better capable of carrying heavy axial load. Use of means for limiting penetration is particularly applicable when the drag cutters are hard and therefore wear resistant, yet subject to impact or failure upon over-penetration. This invention has essentially no applicability in steel drag bits for soft formations.

If desired, one may use diamond cutters near the center of the hole being drilled (with or without a core) and on the hole gage with carbide insert rolling cone cutters drilling an annulus therebetween. Many other modifications and variations will be apparent to one skilled in the art, and it is therefore to be understood that the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A rotary rock bit comprising:

a bit body having a longitudinal axis of rotation;

a plurality of diamond cutters each having a cutting edge protruding from the bit body for engaging the bottom of a hole being drilled at a selected rake angle for shearing rock in a plurality of paths concentric with the axis of the bit body; and

means for limiting depth of penetration of the diamond cutters into the rock to less than the distance of protrusion of the diamond cutters from the bit body comprising a plurality of rolling cone cutters mounted on the bit body for rotation upon rotation of the bit body, each rolling cone cutter comprising a plurality of carbide inserts protruding from the surface of the rolling cone cutter a distance less than the distance of protrusion of the diamond cutters from the bit body in the axial direction for engaging the bottom of the hole being drilled and for crushing or gouging of rock in a path concentric with the portion of the hole drilled by the diamond cutters.

2. A rock bit as defined in claim **1** wherein the rolling cone cutters are mounted relatively nearer the axis of the bit body and the diamond cutters are mounted relatively nearer the periphery of the bit body for drilling an annulus around the portion of a hole drilled by the rolling cone cutters.

3. A rock bit as defined in claim **1** wherein the diamond cutters are mounted relatively nearer the axis of the bit body and the rolling cone cutters are mounted relatively nearer the periphery of the bit body for drilling an annulus around the portion of a hole drilled by the diamond cutters.